Where did infectious disease models come from?

II.

The problem before us is as follows. Suppose that we have a population of living things numbering P individuals, of whom a number Z are affected by *something* (such as a disease), and the remainder A are not so affected; suppose that a proportion $h\,.\,dt$ of the non-affected become affected in every element of time dt, and that, conversely, a proportion $r\,.\,dt$ of the affected become unaffected, that is, revert in every element of time to the non-affected group; and, lastly, suppose that both the groups, the affected and the non-affected, are subject also to possibly different birth-rates, death-rates, and immigration and emigration rates in an element of time; then what will be the number of affected individuals, of new cases, and of the total population living at any time t?

For the solution of this and the subsidiary problems I have ventured to suggest the name "Theory of Happenings." It covers many cases which occur not only in pathometry but in the analysis of questions connected with statistics, demography, public health, the theory of evolution, and even commerce, politics, and statesmanship. The name *pathometry* (*pathos*, a happening) was previously suggested by myself in antithesis to *nosometry* (*nosos*, a disease) for the quantitative study of parasitic invasions in the individual.

III.

(i) Let ndt, mdt, idt, edt denote respectively the nativity, mortality, immigration, and emigration rates of the non-affected part of the population in the element of time dt; and $\mathrm{N}dt$, $\mathrm{M}dt$, $\mathrm{I}dt$, $\mathrm{E}dt$ denote the similar rates among the affected part. Then, as argued in my previous writings and as will be easily seen, the problem before us may be put in the form of the following system of differential equations:—

$$d\mathrm{P} = (n-m+i-e)dt\,.\,\mathrm{A}+(\mathrm{N}-\mathrm{M}+\mathrm{I}-\mathrm{E})dt\,.\,\mathrm{Z}, \tag{1}$$

$$d\mathrm{A} = (n-m+i-e-h)dt\,.\,\mathrm{A}+(\mathrm{N}+r)dt\,.\,\mathrm{Z}, \tag{2}$$

$$d\mathrm{Z} = hdt\,.\,\mathrm{A}+(-\mathrm{M}+\mathrm{I}-\mathrm{E}-r)dt\,.\,\mathrm{Z}. \tag{3}$$

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A Contribution to the Mathematical Theory of Epidemics.

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The problem may be summarised as follows: One (or more) infected person is introduced into a community of individuals, more or less susceptible to the disease in question. The disease spreads from the affected to the unaffected by contact infection. Each infected person runs through the course of his sickness, and finally is removed from the number of those who are sick, by recovery or by death. The chances of recovery or death vary from day to day during the course of his illness. The chances that the affected may convey infection to the unaffected are likewise dependent upon the stage of the sickness. As the epidemic spreads, the number of unaffected members of the community becomes reduced. Since the course of an epidemic is short compared with the life of an individual, the population may be considered as remaining constant, except in as far as it is modified by deaths due to the epidemic disease itself. In the course of time the epidemic may come to an end. One of the most important probems in epidemiology is to ascertain whether this termination occurs only when no susceptible individuals are left, or whether the interplay of the various factors of infectivity, recovery and mortality, may result in termination, whilst many susceptible individuals are still present in the unaffected population.